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REPORT NO. 315/14

TOOL STEELS

BRAZING OF HIGH SPEED STEEL TIPS

TO LOW ALLOY STEEL SHANKS

by

B. S. Lement
Jr. Metallurgist

W. B. Kennedy
Tool Engineer

May 23, 1942

WATERTOWN ARSENAL
WATERTOWN, MASS.

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Report No. 315/14
Watertown Arsenal
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May 23, 1942

TOOL STEELS

Brazing of High Speed Steel Tips to Low Alloy Steel Shanks

OBJECT

To study the feasibility of copper and silver brazing for joining high speed steel tips to low alloy steel shanks.

REFERENCE

W.A. 470.1/5628

CONCLUSIONS

1. High-speed steel tips may be joined to low alloy steel shanks by two methods, as follows:

   a. Braze-hardening: Copper brazing and simultaneous hardening of high-speed steel tips can be accomplished in a single operation.

   b. Braze-tempering: Silver alloy brazing and tempering of previously hardened high-speed steel tips can be accomplished in a single operation.

2. High-speed steel tipped tools give performance equal to that of solid high-speed steel tools.

3. The use of high-speed steel tipped tools is capable of saving large quantities of strategic elements normally consumed in solid tools of high-speed steel.

4. A special high-speed steel composition containing an increased amount of strategic vanadium possesses advantages in certain machining operations, and can be used in tips. By the use of these tips, considerably less vanadium (and other strategic elements) is used than employed in solid tools of ordinary high-speed steel.

5. The use of high-speed tipped tools can operate to reduce tool costs materially, as follows:

<u>a</u>. by requiring considerably less high-speed steel;

<u>b</u>. by eliminating reforging and reheat treating operations customarily used to reclaim worn tools;

<u>c</u>. by reducing the time necessary to make up tools;

<u>d</u>. by salvaging undersize solid high-speed steel tools.

B. S. Lement

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Jr. Metallurgist

W. B. Kennedy

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Tool Engineer

APPROVED:

H. H. Zornig
Colonel, Ordnance Dept.
Director of Laboratory

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INTRODUCTION

The present emergency has focussed attention on the problem of conserving high speed steel because it contains relatively large percentages of strategic tungsten, chromium, vanadium, and cobalt (in special types). High speed steels containing 18% tungsten are being replaced by molybdenum high speed steels in which the tungsten content has been substantially reduced. Despite this important advance, much more remains to be done since the content of the other strategic metals is the same and molybdenum itself may become strategic. One method of conserving high speed steel is to increase tool efficiency by devoting proper attention to such factors as tool design, heat treatment, grinding procedure, and cutting conditions. However, there still remains the problem of waste due to the fact that only a very small amount of a tool is actually used up in cutting. To minimize this condition, the possibility of making tools by joining high speed steel tips to low alloy steel shanks was investigated.

Success along these lines with carbide tipped tools suggested that brazing might also be applied to the tipping of tools with high speed steel. Brazing media for carbide tipped tools are copper, Tobin bronze, and silver solder. The shanks are generally made of low alloy steels having carbon contents between 0.40 and 0.60%. A wide variety of steels may be used, but a silicon-manganese steel of the chisel steel type has been found to possess the best all-around properties. Carbide tips are usually copper brazed in a furnace having a controlled or other suitable reducing atmosphere, although an oxy-hydrogen torch with excess hydrogen is occasionally used. Silver soldering or brazing of carbide tips is mainly accomplished by means of an oxyacetylene torch.

To apply copper brazing to the tipping of tools with high speed steel, it is necessary that the brazing operation be carried out at a temperature that will permit satisfactory hardening of the tip. Molybdenum high speed steels are suitable since they have a hardening range of 2150 to 2250°F or 170 to 270°F above the melting point of copper. By soaking the tip in this temperature range, allowing the copper to set by cooling in air, and finally quenching in oil, the tip will be brazed to the shank and also be in the hardened condition.

Silver brazing is also applicable, but the low melting point of commercial silver solder (about 1200°F) prohibits using the same procedure as with copper brazing. However, by using previously hardened tips, it is possible to braze the tip and temper it, thus developing secondary hardness at the same time. Since the melting point of silver solder is higher than the usual tempering temperature of high speed steel, it is imperative that very short brazing times be employed to avoid overtempering of the tip.

TEST PROCEDURE

1. Braze-Hardening

a. Procedure

Experimental brazing of high speed steel tips was carried out in a Firth Braze-Rite furnace designed for the brazing of carbide tips using a hydrogen atmosphere. The thermocouple in this furnace is located in the heating chamber which surrounds the muffle in which the brazing is accomplished. It was first necessary to calibrate the furnace pyrometer by means of a platinum/platinum-rhodium test couple placed inside the muffle in order to be able to control the brazing temperature. The following calibration was obtained:

Furnace pyrometer reading	Brazing temperature
2225°F	2050°F (brazing temperature for carbide tips)
2375°F	2225°F (hardening temperature for Mo-Max high speed steel)

The high speed steel tips to be copper brazed were made of Mo-Max steel having the following chemical limits:

C	Mn	Si	Cr	W	V	Mo
.76-.82	.10-.35	.15-.45	3.5-4.10	1.30-2.0	.90-1.30	8.25-9.50

The shanks were made of silicon-manganese tool steel having the following approximate composition:

C	Mn	Si	V	Cr
.55	.85	2.10	.30	.25

After several trials the following procedure was adopted in braze-hardening Mo-Max high speed steel tips to silicon tool steel shanks:

(1) Cover the end of the shank to be tipped with brazing flux and push tool into preheating chamber of brazing furnace, allowing flux to melt and spread over surface.

(2) Withdraw shank from furnace, fit tip and shank together with strips of copper both beneath and on top of tip, and cover copper with additional brazing flux.

(3) Preheat tool with tip in place in preheating chamber of furnace until tip attains temperature of approximately 1500°F.

(4) Move tipped end into high heat portion of brazing furnace operating at 2225°F, allow tip to reach this temperature, and soak for one additional minute.

(5) Remove tool from furnace, press tip firmly in place until copper braze sets.

(6) Quench tool in oil to below 200°F.

(7) Temper at 1050°F for two hours.

Previous to brazing, both the tips and ends of the shanks to be tipped were cleaned by immersion in carbon tetrachloride. The total time involved in braze hardening varied but was generally under twenty minutes for each tool.

<u>b.</u> <u>Performance of Braze-Hardened Tools</u>

Two lathe tools 1" x 1-1/2" x 10" long were braze-hardened according to the above procedure using tips measuring 1/2" x 1" x 1-1/4" long. The hardness attained in the tips after tempering was found to be Rockwell C-65.

One of these tools was subjected to a lathe test in comparison with a forged 18-4-1 high speed steel ground to similar angles. The metal machined was Standard Watertown Arsenal gun steel, Brinell hardness 225-250, using a speed which averaged 65 S. F. M., .014" feed, and 5/32" depth

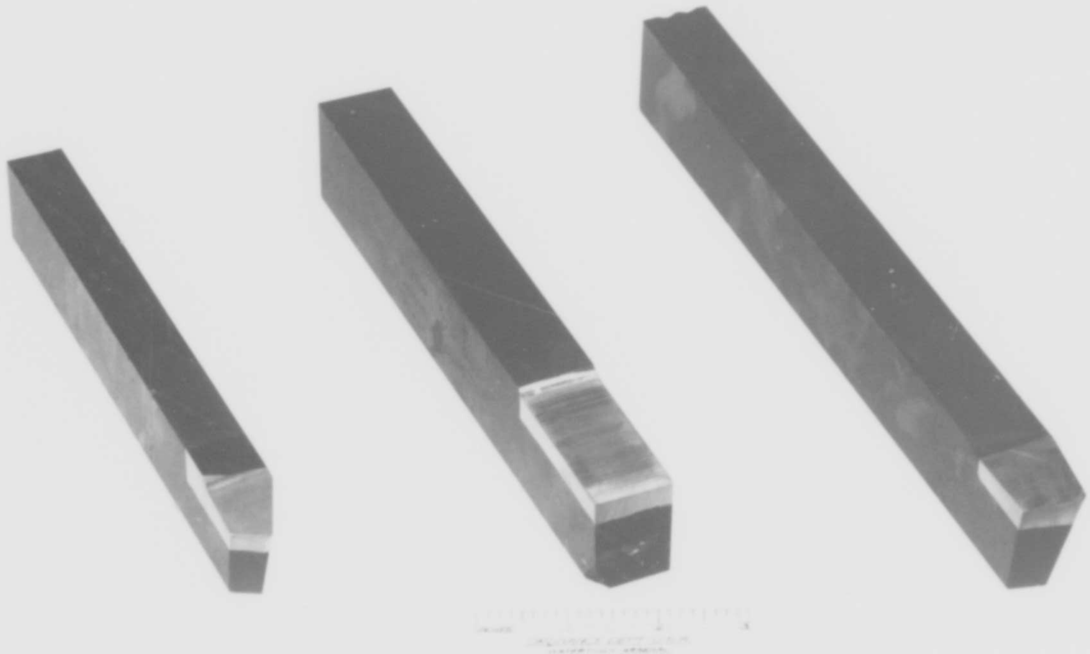

FIG I BRAZE – HARDENED MO–MAX HIGH SPEED STEEL TIPPED TOOLS
MAY 12 1942 W.A.693-39

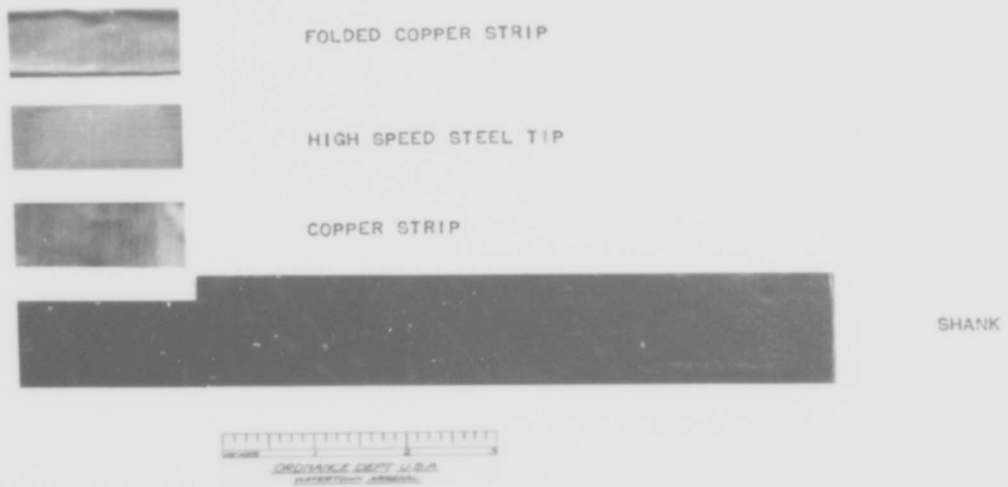

FIG 2 ASSEMBLY FOR COPPER BRAZING OF HIGH SPEED STEEL TIP
MAY 12 1942 W.A.693-40

Tip - Mo-Max High Speed Steel
Shank - Silicon-Manganese Tool Steel
Brazing Material - Copper
Brazing Temperature - 2225° F.

Si-Mn Tool Steel Shank | Mo-Max Tip

17.0	16.5	16.5	15.5	16.0	16.5	17.5	16.5	29.5	42.0	45.5	47.5	46.5	46.5	65.5	65.0	65.5	65.0
13.5	13.0	14.5	14.5	14.5	13.5	14.5	14.0	24.5	40.5	44.5	47.0	47.0	48.5	47.5	46.5	46.5	45.5
13.5	14.5	14.0	14.0	14.5	14.0	16.5	16.0	23.5	39.0	44.0	46.5	46.5	48.5	47.0	47.0	46.5	45.5
14.5	11.5	13.5	13.5	15.0	15.0	14.5	14.5	21.5	40.5	44.5	46.5	46.5	47.0	47.5	48.5	46.5	46.5
16.5	16.0	16.5	16.5	15.5	18.5	17.0	17.0	24.5	40.5	43.5	45.5	45.0	48.0	46.5	47.5	45.5	45.5

(drawn actual size)

Fig. 3 Rockwell "C" Hardness Survey of Braze-Hardened Mo-Max High Speed Tipped Tool Tempered for Two Hours at 1050° F.

W.A.639-4113

of cut. Both tools dulled after approximately the same amount of work and showed equal amounts of wear and cratering on the cutting edge. The braze was unaffected by the cutting test even though more heat was developed in the high speed steel tip than is usually experienced in a carbide tool.

The other tool was used in a shaper machine to test the shock resistance of the braze during intermittent cutting. The material cut was silicon tool steel (same as used in shank) using a feed of 0.32" and 1/10" depth of cut. Twenty-four passes, 1-1/2" long, at the rate of 60 strokes per minute, which covered 6" of cross travel had no effect on the braze. However, the high speed steel tip showed a slight amount of cratering which is to be normally expected for the amount of work performed. However, considerable additional work could have been accomplished without necessitating a regrind.

Subsequent to these initial tests, a number of braze-hardened Mo-Max high speed steel tipped tools were made. These are performing satisfactorily in production. Three Mo-Max tipped tools are shown in Fig. 1. The assembly used in copper brazing is illustrated in Fig. 2 for a tool 9" long, 1-1/4" high and 5/8" wide. A folded copper strip is placed on the tip and a single strip is placed between the tip and shank. During the brazing, the copper on top of the tip melts and actually flows in between the tip and shank. After braze-hardening and tempering at 1050°F for two hours, a hardness survey was made on this tool, as shown in Fig. 3. The tip attained a uniform hardness of about Rockwell C-65 while hardening of the shank occurred for a distance of about 5" from the front of the tool.

2. Braze-Tempering

a. Procedure

As an alternate method of joining high speed steel tips to low alloy steel shanks, silver brazing was investigated. This type of brazing was carried out by means of an oxyacetylene torch using Easy-Flo No. 3 silver solder, melting point 1195°F, recommended for carbide tips. A special composition, Neatro high speed steel was selected as particularly suited to braze-tempering because it possesses greater resistance to softening during tempering than any of the ordinary high speed steels. Neatro has a high vanadium and carbon content which confers exceptional resistance to abrasion. The composition of this steel is:

C	Mn	Si	W	Mo	Cr	V
1.25-1.30%	.20-.30%	.20-.35%	5.25-5.75%	4.25-4.75%	4.25-4.75%	3.75-4.25%

Neatro tips were hardened previous to brazing according to the following recommended treatment:

(1) Preheat at 1450°F for 20 minutes

(2) Raise to 2225°F and hold 1 minute at temperature

(3) Oil quench (Resulting hardness Rockwell C-65)

The braze-tempering procedure developed involved the following steps using the same shank steel as with copper brazing:

(1) Fit shank and tip together with an intervening strip of silver solder. All surfaces to be brazed should be clean and covered with powdered brazing flux.

(2) Heat tipped end with oxyacetylene torch until silver solder melts.

(3) Allow tool to cool in air and press tip firmly in place until silver solder solidifies.

(4) Quench tipped end in oil until the temperature drops below 1000°F, then remove from oil and cool in air to room temperature.

(5) Stress relieve tip by tempering at 1050°F for one hour. The above procedure differs from silver brazing of carbide tips in that care must be taken to avoid overtempering. This is accomplished by minimizing the time between the melting and solidification of the silver solder. By quenching the tipped end in oil for a few seconds after solidification of the silver solder, the temperature is lowered below 1000°F and effective tempering ceases. By removing the tool from the oil and cooling in air, transformation of the retained austenite present in the hardened high speed steel tip is allowed to occur more uniformly and with less danger of cracking. A subsequent temper at 1050°F is recommended for the purpose of stress relief and will have practically no effect on the hardness of the tip.

<u>b</u>. <u>Performance of Braze-Tempered Neatro Tipped Tools</u>

A medium size goose-necked tool having a Neatro tip with a cutting edge 1-5/8" long was made by braze-tempering. Steps 1-4 took about fifteen minutes. The hardness of the tip after Step 5 was found to be Rockwell C 65. This tool was used to finish machine the top surfaces of ten 5" Navy Mount Stands (Drawing No. 217335) having an outer diameter of 114" and an inner diameter of 90.5". This application demands a tool with a cutting edge possessing considerable abrasion resistance at a speed too low for carbide tipped tools, under 75 surface feet per minute. The Neatro tipped tool performed better than any high speed steel tool previously tried for this job. The machined surface passed a more rigid inspection test for flatness, and an auxiliary grinding operation usually necessary to remove high spots was eliminated. The same tool was used to finish machine

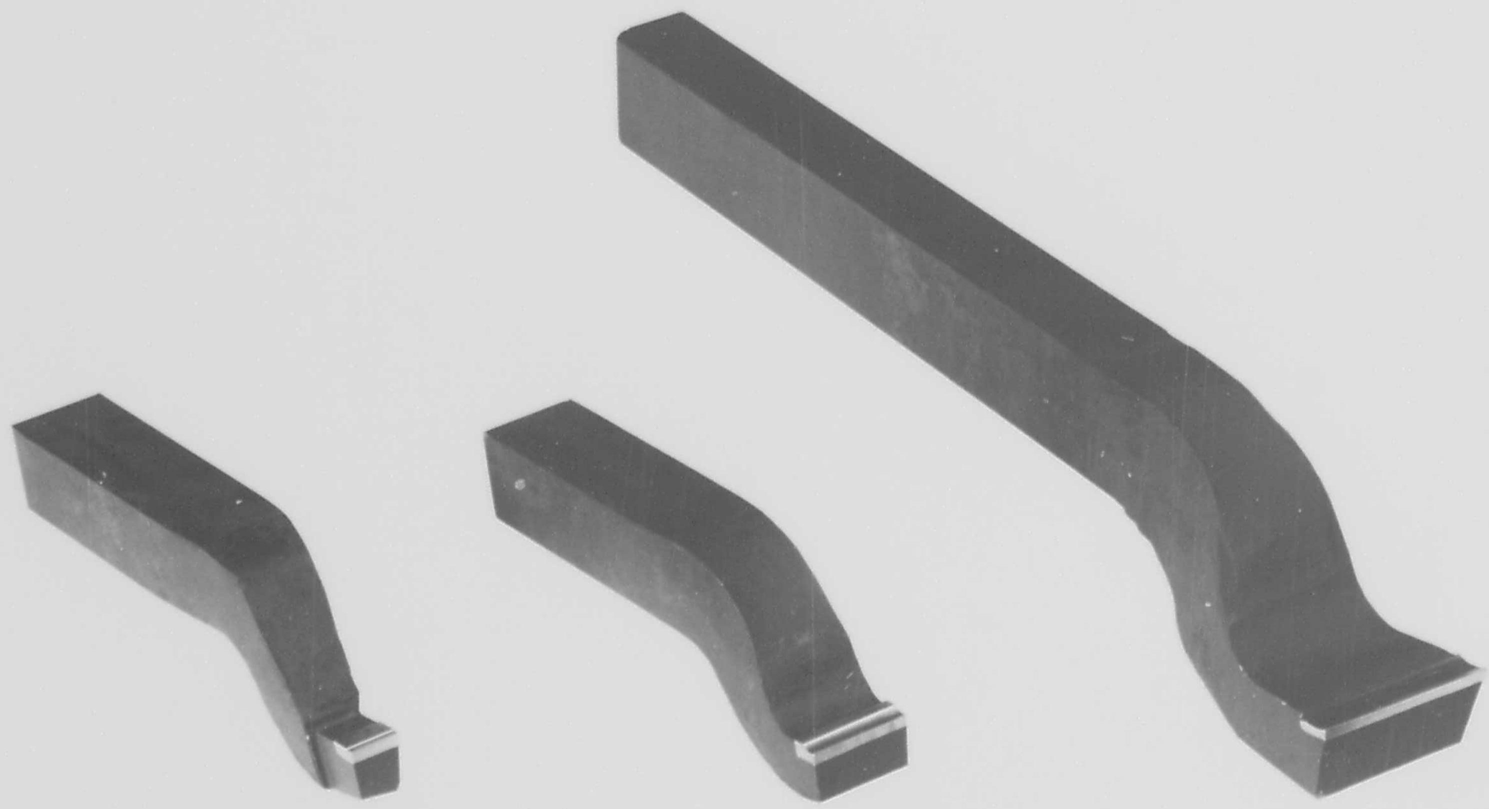

FIG 4 BRAZE — TEMPERED NEATRO HIGH SPEED TIPPED TOOLS
MAY 12 1942 W.A.693-41

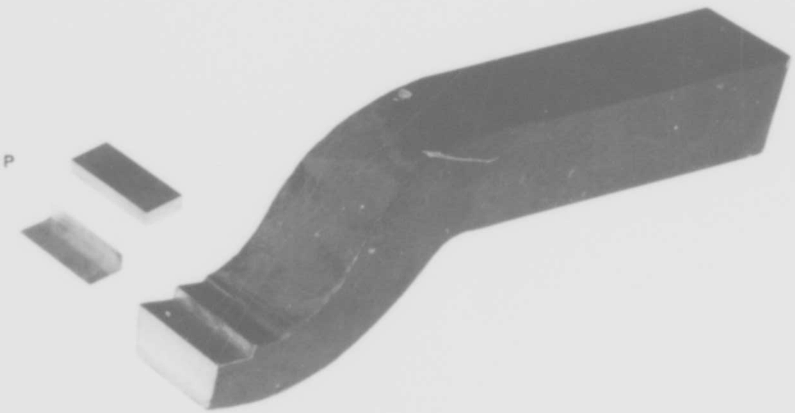

FIG 5 ASSEMBLY FOR SILVER ALLOY BRAZING OF HIGH SPEED STEEL TIP
MAY 12 1942 W.A.693—42

Tip - Hardened Neatro High Speed Steel
Shank - Silicon-Manganese Tool Steel
Brazing Material - Easy Flo No. 3 Silver Solder
Brazing Temperature - About 1200° F.

Si-Mn Tool Steel Shank | Neatro Tip

8.5	12.0	15.0	13.5	16.5	16.0	15.0	14.5	16.0	16.5	16.0	14.5	14.5	16.0	54.5	65.0	65.5	55.0
13.0	14.5	16.0	15.5	15.0	19.0	18.5	15.0	16.0	16.0	14.0	16.5	16.5	14.5	15.0	15.0	15.5	16.0
13.5	14.0	16.5	15.5	15.0	15.0	12.5	16.0	16.0	18.0	17.5	15.5	15.5	17.5	23.0	20.5	16.5	17.5
14.5	15.5	13.5	16.5	16.5	15.5	16.0	16.5	17.5	17.5	16.0	18.0	31.0	35.0	34.5	33.5	29.5	17.5
13.0	13.5	14.5	14.5	17.5	15.0	16.0	16.0	13.5	14.0	18.5	29.5	48.5	42.5	43.5	44.0	43.5	38.0

(drawn actual size)

Fig. 6 Rockwell "C" Hardness Survey of Braze-Tempered Neatro High Speed Steel Tipped Tool.

W.A.639-4114

the bottom surfaces of a 6" Racer (Drawing No. D42459) having an outer diameter of 120" with similarly successful results.

A number of goose-necked tools tipped with Neatro high speed steel were made, three sizes of which are shown in Fig. 4. The largest tool shown in this figure measures 20" in length and weighs eighteen pounds while its tip weighs only about two ounces or less than one per cent of the tool. The assembly used in braze-tempering is illustrated in Fig. 5. These tools have been placed in service and are performing satisfactorily.

For the purpose of comparison with the braze-hardening method, a hardness survey was taken of a braze-tempered Neatro-tipped tool having the same size as the tool illustrated in Fig. 3. As shown in Fig. 6, the tip retained its initial high hardness, but the hardness of the shank was unaffected except directly below the tip where the temperature exceeded the critical by direct contact with the oxyacetylene flame and the subsequent oil quench caused hardening.

c. Performance of Braze-Tempered Mo-Max Tipped Tool

An experiment was made to determine whether or not braze-tempering could be applied to ordinary high speed steels such as Mo-Max. A lathe tool (Same size as shown in Fig. 3) was made by braze-tempering a previously hardened Mo-Max tip using Easy Flo No. 3 silver solder. By taking special pains to minimize the brazing time, it was found possible to retain the high hardness of the tip (Rockwell C 65). This tool was used without further tempering to take a finishing cut on a 1-1/2" diameter bar of WD-2340 steel, Brinell Hardness 225. Four passes over 14" of length were taken at a surface speed of 80 feet per minute employing a feed of .022" per revolution and 1/16" depth of cut. The tool performed satisfactorily and no weakening of the brazed joint was observed.

DISCUSSION OF RESULTS

1. Comparison of Braze-Hardening and Braze-Tempering Methods

The results of the various machining tests indicate that both copper and silver alloy brazing are capable of producing tipped high speed steel tools which perform as well as solid high speed steel tools. The braze-hardening method using copper as the brazing medium is applicable to the common molybdenum high speed steels since they have a hardening range not too high above the melting point of copper. The braze-tempering method using silver solder is particularly suited to Neatro steel, but can however, be applied to other high speed steels as well provided that special care is taken to minimize the brazing time. This method would require less careful control if solders having lower melting points (1050° to 1100°F) and capable of producing a strong brazed joint could be developed.

As compared with the braze-hardening method, the braze-tempering method is less suited to making tools required to take heavy cuts. In taking heavy roughing cuts, sufficient heat may be developed to cause softening of the silver alloy braze and consequent movement of the tip. For this reason, it is preferable to use braze-tempered tools mainly for finishing cuts. Since, however, copper softens at a much higher temperature than silver solder, braze-hardened tools can be used to take either roughing or finishing cuts, as desired. Another advantage of the braze-hardening method is that substantial hardening of the shank takes place while the braze-tempered shank is relatively unhardened. This means that the braze-hardened shank is stronger and will have less tendency to take a permanent set due to bending in taking a heavy cut. Of course, the shanks used for braze-tempered tools could be previously hardened to develop strength equivalent to that secured in braze-hardened shanks, but an extra heat treating operation is required.

2. Selection of Shank Steel

The shank steel used in this investigation is a composition recommended by the Carboloy Company for use with carbide tips. Since this particular composition contains 0.30% vanadium and 0.25% chromium, its use for both carbide and high speed steel tipped tools is to be discouraged. Silicon-manganese steel without vanadium and chromium and even plain carbon steels have been used for carbide tipped tools and would therefore be expected to be satisfactory for high speed tipped tools. Since, however, the braze-hardening operation is carried out at a temperature about 175°F above the usual copper brazing temperature for carbide tips, it is necessary that shank steels to be used with high speed steel tips possess greater resistance to grain coarsening and structural damage by the high temperature. This requirement is not necessary in the case of braze-tempered tools because the shanks are subjected to a much lower temperature, and even plain carbon steels may be used. An investigation is in progress to determine the alloy requirements of shank steels to be used in braze-hardened tipped tools.

3. Advantage of Tipped High Speed Steel Tools

There are several advantages in using tools tipped with high speed steel by the brazing method. First in importance is the saving of high speed steel which means conservation of strategic metals as well as lowering of tool cost. The amount of high speed steel saved depends upon the design of the tool. For ordinary straight lathe tools, the minimum saving is estimated as 75% while for special shaped tools such as form cutters or goose-necked tools it may be as high as 99%. This economy makes it possible to use special high speed steels such as Neatro and the cobalt types which give better performance than ordinary high speed steels in certain applications. Although these special compositions contain relatively large percentages of strategic metals, their use in tipped tools would be practical.

As an example, consider the case of a medium size goose-necked tool weighing 5-1/2 lbs. tipped with Neatro high speed steel which contains 4% of strategic vanadium. The weight of the tip is under 2 ounces, or roughly 1/50 the weight of the entire tool. The vanadium content of the entire tool (assuming the shank steel contains no vanadium) amounts to about 0.08%. Compared with the vanadium in a solid Neatro high speed steel tool (4%) which would give the same life or in a solid tool of ordinary high speed steel which would perform far less efficiently, the consumption of vanadium in Neatro tipped tools is insignificant.

The majority of forged high speed steel tools used in production are reground after each dulling until the tool height is reduced to about two-thirds of its original size. The tools are then sent to the forge shop where the cutting ends are cropped off and the remainders are reforged. After forging the tools are annealed and rehardened. This process is repeated until about one-half of the original length of each tool is used up. The remaining half is usually too short to be clamped and is, therefore, scrapped. All of these operations are time-consuming as well as wasteful and add to tool cost. They can be eliminated by the economically superior brazing methods. Furthermore, even the solid high speed tools which have been discarded as undersize can be salvaged after reannealing and cutting into tip sizes.

4. Application of Tipped Tools

A patent search was undertaken to determine the novelty of the braze-hardening and braze-tempering methods. Results to date (see Inclosure I) indicate that the braze-tempering method is novel, but that several patents on the braze-hardening method have been granted and most of them have already expired. Since braze-hardened high speed steel tipped tools are not being used extensively (if at all), it is concluded that they did not prove successful in the past. This may have been due to the difficulty in obtaining a strong brazed joint. Until recently, the technique of copper brazing was not very well developed. Furthermore, only tungsten high speed steel was available, which because of its higher hardening temperature, is more difficult to braze successfully than molybdenum high speed steel.

In any event, both methods studied at this arsenal have proven successful and no obstacle stands in the way of their adoption. These methods have been used mainly for lathe tools but can be applied to other types of cutters. The limiting factor in applying these methods is the difficulty involved in brazing and, therefore, they would be of no advantage in making complicated drills or special shaped cutters. It is estimated that tipped tools could be used in applications which require at least three-quarters of the high speed steel used at this arsenal. If adopted on a nation-wide scale, tipped high speed steel tools would result in considerable saving of strategic metals.

APPENDIX A

COPY /kgc

W.A. 470.1/5628
Attn: Patent Section 1st Ind. WAS/jwm

Captain Wilbur A. Schaich, Springfield Armory, Mass., To: The Commanding General, Watertown Arsenal, Watertown, Mass.
Attention: Laboratory (BSL)

1. A novelty and infringement search has been completed by the Patent Section of the Office of the Chief of Ordnance upon the two proposed methods of tipping low alloy steel shanks with high speed steel developed at his Arsenal.

2. The references discovered in the course of this search indicate that no patentable novelty exists in the proposed braze-hardening method. The following patents, copies of which are enclosed, illustrate that this method is well known in the art:

Patent No.	848,112	-	Matthews
" "	848,161	-	Dierig
" "	949,377	-	Matthews
" "	1,186,094	-	Heinkel
" "	1,290,042	-	Arnold
" "	1,339,152	-	Arnold
" "	1,797,026	-	Sharp
" "	1,798,314	-	Dillard

3. Several additional references are still forthcoming from the Patent Section of the Office of the Chief of Ordnance. Unless these expected references prove otherwise, it appears that the second proposed method, namely, the braze-tempering method, is novel and may properly be the subject of a patent application. If such is the case, the patent application will be prepared by Captain Schaich.

4. Based on the results of the search received to date it appears that there are no unexpired patents which would be infringed by the practice of either of the two methods. The patent situation should therefore not be considered at this time to present any obstacle to the adoption of either of the two methods by his Arsenal.

/s/ Wilbur A. Schaich,
Captain, Ord. Dept.,
Assistant

4 Encls. w/d
8 Encls. added
(Patents